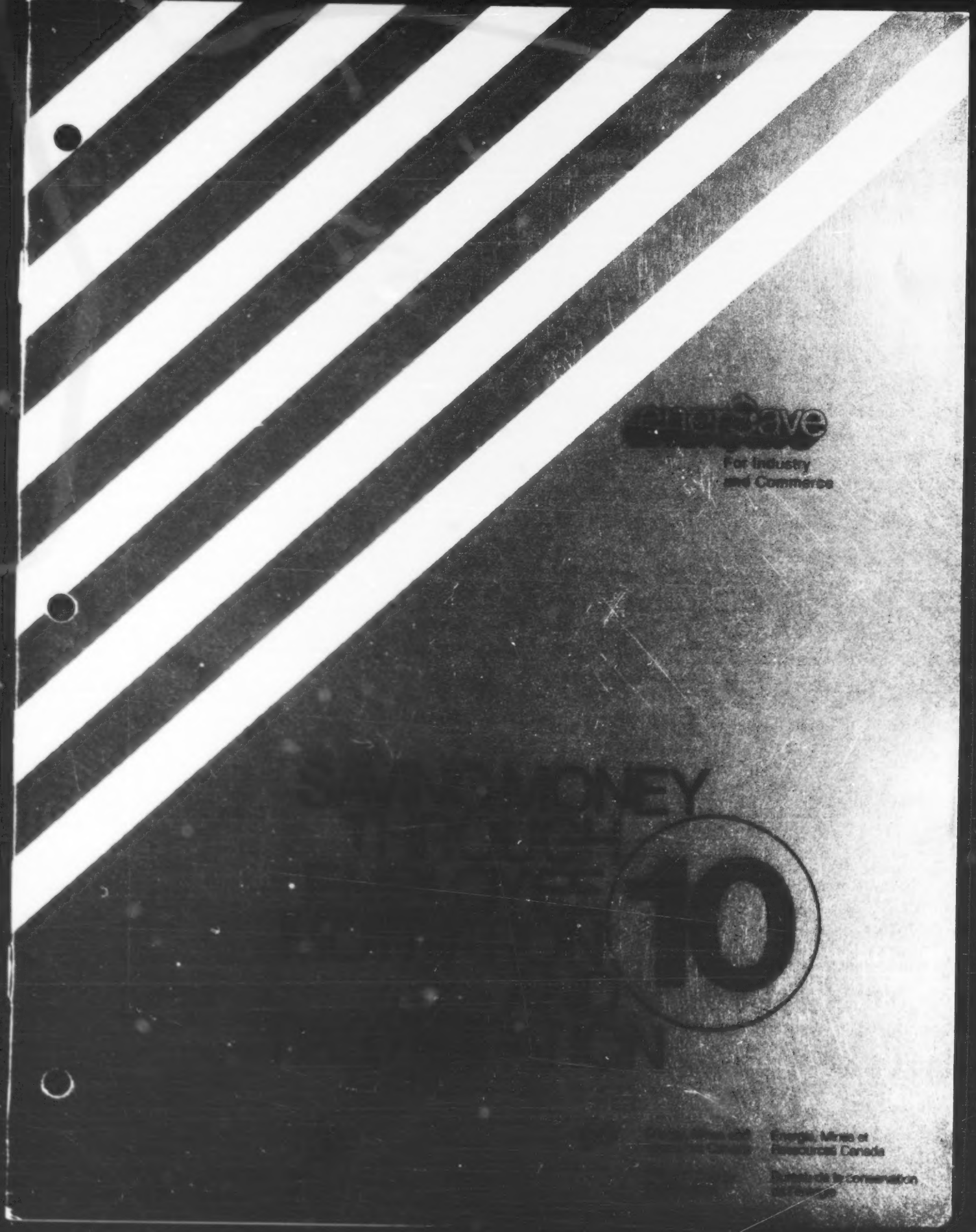
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Energy, Mines and
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# SAVING MONEY THROUGH EMPLOYEE MOTIVATION AND PARTICIPATION 10

# Saving money through Employee Motivation and Participation

## Introduction:

In most of the booklets in this series, a good deal of stress is put on the need for automatic controls, timers and switches that will remove much of "the human factor" from day-to-day energy conservation.

This booklet emphasizes one major premise — that well-motivated employees are and always will be an essential ingredient in successful industrial energy conservation programs.

It deals with some of the broader issues involved and gives specific examples of the types of programs Canadian companies are undertaking to motivate and involve their employees in energy conservation.

## People motivation — the key to a successful energy conservation program

The success of any energy conservation program depends largely on the extent to which people get involved. This means everyone — from top management to the worker on the production line.

Simply stated, there is little sense starting a program if management is not ready to endorse it wholeheartedly — with dollars as well as words. On the other hand, there is little point spending thousands of dollars re-insulating a plant if employees are not motivated to keep loading doors shut. And what good is turning down the heat, if uninspired or uninvolved employees bring in portable electric heaters which waste more energy than is saved?

Employees must be educated as to the reasons for energy conservation, and they must be involved personally in some way. Only if everyone in a plant "pulls together" will a program be truly meaningful and most effective.

The employee involvement must be a continuing one. If the conservation effort lets up, interest will wane. Old habits reappear and much of the ground gained is lost. It is easy to turn the thermostat back up — and there go the savings. If maintained by employees, heat recovery systems, temperature control valves and other mechanical systems will continue to generate savings, but casual waste will fluctuate with employee interest in, and commitment to, energy conservation in the plant.

As a simple rule: involve your employees in energy conservation and keep them involved!

## A crucial element — support from the top

Employees can tell when a conservation effort is just tokenism — and one dead giveaway is a lack of highly visible support from the top.

Certainly, management support is a necessary part of any energy conservation program if people are to be properly motivated to achieve savings, and management support requires more than someone giving the nod to a conservation program and assuming the plant manager will just "fit this little job" into his busy schedule. Management participation means management that is committed to getting energy savings with the same intensity that it would place on extracting similar profits from increasing production.

An announcement concerning energy conservation should come from a company's senior executive early on in the program. He should make clear his commitment to conservation in some way — via the company newspaper, notices on all bulletin boards, or letters to employees. He should inform all employees that a program is being started, outline the reasons for it, name the committee and co-ordinator and outline the guidelines under which the committee is to operate. This top executive should show his continuing interest and concern by checking on progress

and accomplishments in the various departments, offering employees congratulations if results are good, and spurring them on to greater efforts.

When management is committed to a program, it constantly checks on progress and asks penetrating questions when results are not forthcoming. If there is a lack of co-operation between departments, explanations are required — nothing is allowed to drift. When a department is found to be slipping behind, obviously not meeting its goals, management can't wait another month to see if it will get back on track. The department that finds it has to explain its activity to management on a weekly basis soon realizes that a token performance is unacceptable.

The most powerful form of management support is example. 3M Company in St. Paul, Minnesota has one of the largest vanpool programs in the United States, and perhaps one of the reasons for its success is that some of the top managers ride to work in vanpools. When an employee sees a senior executive turn off the lights when he leaves the room for a few minutes, or take public transit to work, he will be reassured that there are no double standards — the program affects everyone!

## Building a dynamic team

Once management support has been enlisted, the next step is to recruit a capable co-ordinator and a plant energy conservation committee.

Ideally, the program should be directed by a full-time person. If one employee can't be dedicated to the job, however, a hard-working individual who has energy conservation high on his list of priorities can still accomplish a great deal when given the support of top management.

The person who co-ordinates the program should provide vigour, initiative and enthusiasm. In addition, he should have technical ability and the ability to communicate with others. But the most important quality is enthusiasm — so others will be caught up in the spirit of saving energy. The co-ordinator also needs tact and must be able to work well in a team. Energy conservation can become a grinding and discouraging job, and it takes a high calibre individual to carry it through successfully.

### Maintaining an Ongoing Program

To maintain continuing enthusiasm in the E.C. program, the following items should be included in the activities of the E.C. co-ordinator, or committee:

1. Hold regular meetings, perhaps monthly.
2. Involve members of all departments, so that they provide the communications link between the committee and plant personnel.
3. Institute and maintain a project and idea list for the plant(s).
4. Calculate energy use per unit of production. This should be done before E.C. is instituted and monitored while E.C. is in progress. Monthly calculations and records are recommended.
5. Attend seminars and participate in E.C. sessions outside the company.
6. Consider outside consultant services in special situations, if necessary.
7. Disseminate posters, booklets, tags, signs to remind plant personnel that E.C. is "in" in that plant.
8. Solicit employee participation in ideas. Some plants have a formal suggestion plan where the employee is rewarded for worthwhile contributions.
9. Publish energy related information to management and committee members in a monthly report, with progress relative to targets or goals set.
10. Publish energy related information periodically to employees by way of bulletins or magazines to inform them of progress and achievements in reducing energy use.

**Company-wide representation**

The energy conservation committee should have representatives from all parts of the company. Certainly, the plant engineering or plant facilities department must be represented, and it is often wise to choose the co-ordinator from this sector.

There are a number of benefits to having all departments represented on the committee. Essentially a problem-solving and action-taking group, the committee is also one of the most effective methods of selling the energy conservation program. Supervisors or department heads should be encouraged to participate in committee activities affecting their areas and assigned specific projects for investigation and follow-up.

Canadian General Electric's Davenport/Royce/Ward complex in Toronto makes the foreman the key figure in its program. In November, 1976, information sessions were held for more than fifty foremen and supervisors, as well as workshop sessions on how to involve plant people in the program. Each foreman develops a program for his area, including "rap" sessions with his people. The workshops were very rewarding, with the foremen pledging their leadership for energy conservation and a free flow of ideas. Among the ideas that emerged at the workshops were team competition between various areas and energy conservation tours around the plant to identify areas of wastage.

The work of the committee includes setting annual objectives in energy savings for each part of the company. It must communicate these objectives to the management in each part of the company and help with the organization of the various departments.

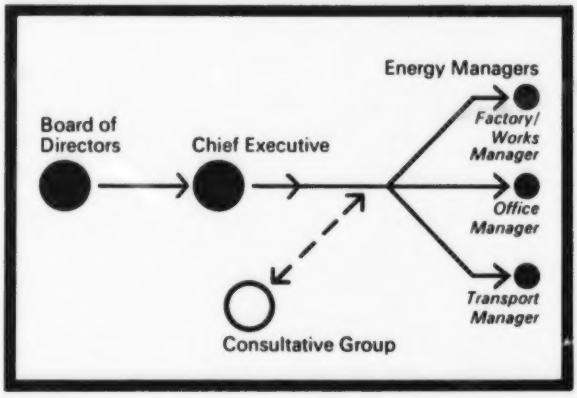
The chart at right shows how a progam could be set up — with support coming from the Board of Directors down through the Chief Executive for the program to representatives from different areas of the company. It is also worth considering the appointment of a specialist energy consultative group drawn from the company's own engineering expertise to provide technical guidance for the program.

The committee should seek support from other very important areas — either by including them in the committee or by seeking advice.

Urge the committee to work hard to obtain union support. Make energy conservation a joint responsibility, perhaps by forming management-labour committees to seek out ways of achieving economies. Most unions will overwhelmingly support energy conservation, particularly if the whole company seems to be committed. Many U.S. workers and their unions have seen devastating effects on employment due to unchecked energy shortages. While the Canadian situation is perceived to be different, Canadian unions are aware of, and share, enlightened citizens' concern for conservation.

The public relations or advertising people in your plant — if there are any — form another important group. Their job is communication, and they are the ones most familiar with the posters, pamphlets, newspaper articles and bulletins that will help tell the energy conservation story. Call on them.

Smaller companies are unlikely to have advertising or public relations staffs. Alternative methods of publicizing energy conservation, geared to a smaller firm, can be equally effective and easily handled by the program organizers. For example, employees could be given the opportunity to participate in a poster contest based on conservation themes in the plant in which they work. It doesn't have to be a professional effort; an amateurish one may be even more effective.



## Motivating through measurement

Measurement is an important part of any energy conservation program. Goals must be set and savings documented if the success of the program can be judged.

To this end, an energy use survey or wasted energy audit should be conducted, department by department, at the beginning of the program and at periodic intervals thereafter. If done thoroughly, it will turn up areas where energy can be saved — through simple housekeeping practices, by retrofitting, or by conversion of systems — and give everyone an idea of where the inefficiencies lie. As time goes on, audits can be done at longer intervals. Some audits should be conducted at night or on weekends when the plant is not operating (see Guidebook for information regarding energy audits), but do not hide the fact that an audit is being conducted during working hours. Some of the provinces have an "energy bus" program whereby a team of experts arrive at the plant and perform a survey of energy use in the plant. Such energy audits are performed on request. If an "energy bus" is available in your province, make an employee "event" out of the initial visit — and publicize its findings.

Most effective energy conservation programs start out by aiming at one specific service — steam, compressed air, electricity — whichever offers the most significant potential improvement. When a specific area is chosen, let everyone know why it was chosen and give them some idea of the energy and dollar savings involved.

Sizable savings can often be achieved by postponing the need for new facilities or services. If the steam system is close to capacity, look at it first. You may derive a double benefit — the direct savings by reducing energy consumption and the indirect savings achieved by not having to invest additional dollars in equipment now. Again, let everyone know — tell them both that the energy conservation program will cut steam consumption by 10% and that this energy saving means you have been able to defer spending $700,000 on a new boiler for another year or so.

Both long-range and short-term goals should be set. It's good to set a target of 30% reduction in energy consumption over three or four years — it provides a continuing incentive — but from the point of view of employee motivation, a shorter attention span is needed. A short-term target of, say four or five percent savings in six months, is something employees can try to meet. The satisfaction of seeing themselves approach and meet short-term goals can be a real "kick" for employees.

## Monitor your energy savings

Given the commitment and managerial organization, the next step is to determine your company's energy requirements. This is crucial in:

—assessing the steps needed to save energy

—measuring the success of the energy-saving program.

Do you know your energy consumption for the various stages of individual processes? Monitor the energy used in each process and keep good records. Then check that savings are being made. Records should be:

—kept as simple as possible

—related to each step in the process

—maintained for constant time periods (e.g. monthly moving averages on an annual basis).

They should record the:

—form of energy and total consumption (expressed in the most convenient accounting units)

—total production associated with total energy consumption

—specific energy consumption associated with specific production, output or performance.

Cost and management accounts may well help to provide much of the basic information needed. The results will help you to:

—establish what you are spending on energy

—identify areas where savings can be made.

All goals should be set in familiar units that all workers will recognize. If they work with and are familiar with pounds of steam per 1,000 pounds of product, use that as a measure. If it is required, transfer the numbers into gallons of automotive gasoline, dollars — as long as it is a unit employees will accept.

Regular reports are another way of keeping employees involved. An analysis of each department's performance should be prepared and presented to management showing current performance, progress to date, and the program's targets. Install meters where possible to measure department energy consumption — or regularly monitor progress and record it on a form such as that used by Bell Canada or 3M (see example). If employees know the company is keeping such strict tabs on their work, they are likely to pay more attention to energy conservation.

**The rivalry incentive**

These reports guide the energy conservation committee in developing the program and they can also generate a little healthy rivalry. Combined reports showing how each section is doing can be circulated throughout the plant. This shows each section its progress and allows comparisons in relation to other sections. Nobody likes to be last, so this type of report can be a valuable incentive to improve poor performance.

Reports on the performance of other divisions or plants within the same company can also create some friendly competition. In one chemical plant, the goal was a 30% decrease in steam usage, to be achieved within three years. The target was based on having enough steam for a new chemical plant without adding extra boilers to the existing plant. If the 30% reduction was made, that branch of the company would get the new plant; if it wasn't, another branch of the company would get the big expansion. Rivalry with the other plant was a big incentive for reducing energy consumption. Even if this approach does not conform with the management policy at your company, the "rivalry" motive is sound.

There are many other ways to involve employees, but John Deere's Welland, Ontario Works employs a unique method — specifically assigning an hourly employee to energy conservation maintenance and energy audit recording. The employee chosen is a third or fourth class stationary engineer. During the first year of the John Deere program, a 23% saving was achieved, exceeding the corporate goal of 20% by 3%. The following year, the stationary engineer was transferred with no replacement. Without any centralized energy conservation maintenance program, the savings dropped to 19%, 6% short of the corporate goal of 25%. The program has now been reinstated.

**Meters have psychological impact**

The physical installation of measuring devices can have a beneficial psychological effect on a department. The fact that consumption is being measured is often enough to cause large load reductions. Besides, without accurate measurement, the performance of a particular piece of equipment or department can not be evaluated. A rule of thumb might be to put in a meter when the annual cost of the service represents five times the cost of the meter. A saving of 20% of one year's consumption will pay for the meter and leave the facilities for continuing to accurately measure and control energy consumption in the area.

Again, the important message is — communicate! Measurement provides employees with a solid indication of their progress and gives them an incentive to work harder — but only if the results are made known.

## Involving all employees

Employees are the backbone of the conservation program. They turn off hot water taps and unnecessary lights and shut off production machinery when not in use, and their participation is not limited to simple housekeeping measures, though these are the ones that depend most on employee action. Whether the company is retrofitting or converting a whole system, conservation savings are ultimately dependent on the employees' personal contributions. Employees are the ones who will run new machinery efficiently — and they should be given training on how to do just that. Even if a company makes big changes to its steam or compressed air systems,

energy savings will be small if employees are not educated on how to work with those systems. And there is little sense fitting a loading dock with air-tight doors, if employees are not taught to keep those doors shut when not in use.

Employees must be involved, informed and motivated in all aspects of the conservation program if maximum savings are to be achieved. Once they are told about the program, and shown examples of waste and poor practice, they can be invaluable. Where lights are turned off automatically or where machinery shuts off at a certain time each day, employee help is less essential. But in the final analysis, there is really no substitute for an enthusiastic worker who understands the need for, and supports, plant energy conservation programs.

Motivating people for energy conservation means coming to grips with a couple of frequently encountered employee attitudes. First, many employees in Canadian companies find it hard to believe there is an energy crisis. Fuel shortages and layoffs due to fuel shortages are things that happen in the United States, not here.

The other attitude is apathy — "What can my efforts do to reduce energy consumption?" If an employee believes that any efforts to turn out the lights and turn down the thermostat are futile, he will not be very enthusiastic about the company program.

There are several ways to tackle these feelings. Energy conservation is something that is easy to relate to if it is "handled" properly, and the employees must be made aware of ways in which it relates to them.

Explain that fuel shortages will happen in Canada. Show them government projections that show an energy shortfall in the early-to-mid 1980s unless something is done to conserve energy — now! Explain what this will mean in terms of job security. This is a "negative" motivator, but in the right context, it is one of a number of ways to get the message across.

Explain what energy conservation means for the company; that Canadian firms must compete in international markets and unless we are thrifty with our energy, the competition is even tougher. Again, this means loss of employment. Better still, explain that if energy thrift is practised, *more* jobs can often be created.

Stress the dollar savings. This "bottom line" approach may or may not have a major impact, depending on the size of the company, the state of employee relations, existence of profit sharing, and the many other factors which affect loyalty to the company.

**Stress participation**

One of the best appeals is to stress the employee's crucial role in energy conservation. Tell him why the program can not function without him. Make him accountable for some area of the program, however small. Appeal to his pride and sense of responsibility.

Use a little psychology. People do not like to be told their old practices were inadequate; instead stress the future and the need to adapt to a new, evolving society based on conservation rather than consumption. Relate this to home heating bills and car gas mileage. After all, you are really asking the employee to help you get more "miles per gallon" out of your plant equipment.

One of the best ways to change the images is by example — by having managers participate in the program to show that conservation does not detract from status. Show the inconsistencies between excessive energy consumption and values held by employees. Such a message might refer to a person's love of the great outdoors, and then show how excessive use of electricity creates a need for new sources of power which can destroy parts of that wilderness.

**The human touch**

Be human. Anticipate the problems that will come up and suggest ways to cope with them. For example, if the thermostat is lowered to 19°C, people frequently feel cold, especially at first. Often, the natural reaction has been to bring space heaters into the office. Explain that such heaters use up a great deal of energy, and suggest that employees wear sweaters.

Do not just unilaterally take out light fixtures, or people are bound to notice and complain. Explain why you are taking the fixtures out, and how you determined that the lighting levels would still be adequate. Make sure light switches are not hidden — if you want people to participate

in the program, show them where the switches are, and if they are in very awkward locations, move them.

Don't be afraid to use humour in your energy conservation program, since the light touch is sometimes the most effective way of getting the point across. That is why editorial cartoons are a staple part of most major newspapers. Some examples of humour used effectively include the federal government's "Garbage Gus" used to encourage consumers to throw out less and conserve energy; and the Etobicoke, Ontario Board of Education's program aimed at school children which uses the cartoon character, "Billy Bulb".

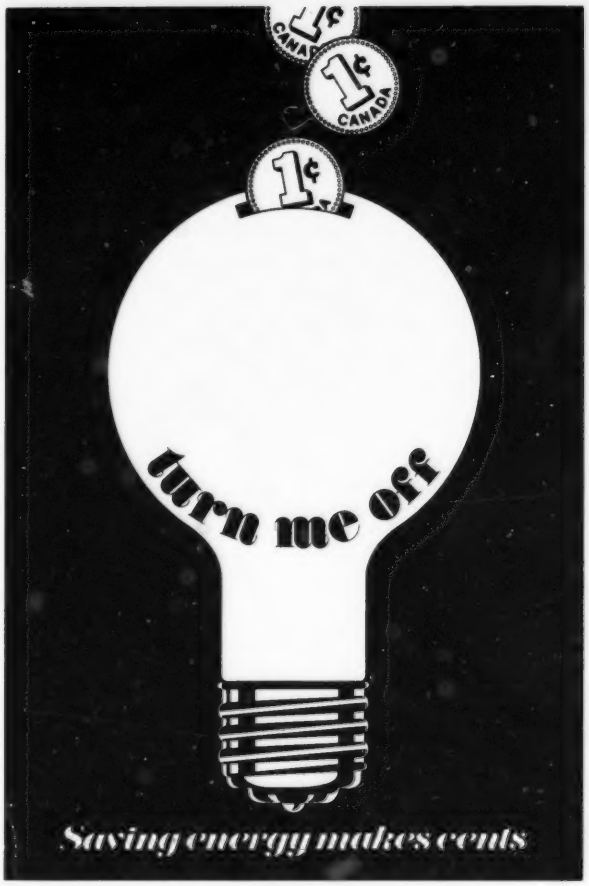
Make sure, however, that the approach taken does not appear to insult the intelligence of your employees.

Since energy conservation involves an attitude change, it is a good idea to send publicity material to the place where many attitudes originate — the home. Sometimes children can put pressure on the parents to develop good energy conservation habits, and sending information home encourages the employee to practice energy thrift in all areas of his life. Why not send a special energy conservation issue of the employee bulletin to the home, stressing the merits of the company program. Stuff memos regarding energy conservation into pay cheque envelopes. Send Office of Energy Conservation booklets to the home — "100 Ways to Save Energy and Money in the Home", "The Billpayer's Guide to Furnace Servicing", and "The Garbage Book". If an employee practices energy conservation at home, he is more likely to do it in the plant.

**Publicizing Energy Conservation**

One of the most effective ways of selling the energy conservation program is a continuing publicity program designed to reach the workman on the job. Such a program should explain your goals, inform people about the cost of losses and point out where major savings and improvements have been made, but above all, it should make the program visible. Think of successful safety programs in which stickers are placed on machines, posters put up on plant walls and tips provided in company newsletters, and follow the lead. The energy conservation committee should use all these publicity

**Bell Canada tent card gets the message across**




methods to make the program known.

Among the ways of publicizing an energy conservation program are:

- A rack of pamphlets in the lunch room or the lobby.
- Tent cards. Bell Canada has used this system. The cards had six different slogans and each slogan was displayed for a two-week period. They were used mainly on company cafeteria tables, but also in reception areas and on office desks.
- Signs and posters around the plant or office.
- Progress charts showing targets and achievements.
- Signs or stickers over taps and lights. One popular type of sticker can be fitted over a light switch.
- Pictures on bulletin boards. This is one of the simplest and least expensive publicity

methods, but it can work well. A picture of a steam leak posted on a bulletin board can be a very effective way of ensuring that future problems of that nature are dealt with quickly.

- Feature items in the company "house organ". One special issue can be devoted to energy conservation, or a series of articles could explain the program. A suggested format for an energy conservation program in the company's newsletter includes the following articles:

1. the president's announcement of the energy conservation program and explanation of the reasons
2. the formation of the energy conservation committee
3. the targets set for the company
4. reports on specific programs as they are carried out
5. soliciting conservation ideas from employees followed later by an article detailing some of these ideas
6. an article regarding the way in which actual savings stack up against the targets.

- Letters and memos from the company's top executive and the program co-ordinator. These are a must. There should be a letter to all employees announcing the program and follow-up letters regarding progress. Some companies make their memos a detailed information package to be sent out to all employees including: the aims of the program; the names of conservation committee members; a brief description of the Canadian energy situation; a description of main energy conservation measures and anticipated savings; and a checklist of conservation measures.

- Contests. These can take many forms — logo contests, slogan contests or contests between departments or divisions of a plant. Some companies already have employee suggestion plans, in which employees are reimbursed for suggestions on the basis of how much money the suggestion will save the company. By setting up a conservation suggestion plan, or including conservation suggestions in the existing plan, employees can be effectively involved.

**Sample sticker from Federal Government Program**

SAVE ENERGY • ECONOMISONS L'ENERGIE
20°C max. heating chauffage max.
25°C min. cooling climatisation min.
SAVE ENERGY • ECONOMISONS L'ENERGIE

- Incentive plans. Shell Canada had a week-long program in late 1976 in which five dollars was given to an employee's favourite charity if he complied with any one of a list of conservation measures during that week. This type of program — with lower dollar incentives, perhaps — could be useful on a continuing basis. Other incentives include reduction of parking lot fees for carpoolers or contribution of money toward public transit fares.

**Employee education**

There is much to be gained by formally educating employees as to the reasons for energy conservation. Distribute books to employees. Send selected employees to seminars. Hold in-plant workshops.

Some companies have set up energy conservation training programs for department heads; and others have included energy conservation in existing training programs.

Shell Canada has focused on one area of education, by setting up a computer simulation of a refinery process furnace to help train process operators and supervisory personnel.

The theory is that by learning more about the variables of efficient furnace operation, the employees will save the company energy and money. Results have been encouraging so far, and benefits include more rapid re-establishment of optimum furnace efficiency following a major process change or plant upset, and improved ability to make furnace adjustments which result in higher furnace efficiencies. The program has proven worthwhile, and Shell estimates that even a 1 percent improvement in furnace efficiency would provide savings of over 50,000 barrels of fuel per year, or $400,000 at current fuel prices.

While smaller plants can't hope to achieve savings of that magnitude, the principle is the same — by training the people that operate the machine, you can save money since that machine will be operated more efficiently.

## Making conservation second nature

With costs of all types of energy on a seemingly straight line increase, conservation is a necessity. Educating people to close doors, turn off lights and spot energy waste is critical — from the point of view of the company and of society as a whole. Without being overly dramatic, energy conservation must become a way of life and Canadian industry has a role to play in helping this to happen.

Involving people in energy conservation means changing habits. Top managers must be willing to participate in the program, even when it means slight changes in their lifestyles. All employees must learn to practise energy thrift in all areas of their daily routines.

Motivating people for energy conservation is a difficult task. Many people do have preconceived notions about energy — "There is no shortage in Canada" or "My efforts will make no difference to overall energy consumption".

But with management support . . . a dynamic team headed by an enthusiastic co-ordinator . . . measurement and reporting of results . . . and continuing publicity and education programs, the job can be done . . . and done well.

Motivate your employees. It is the key to a successful energy conservation program.

## Tips on employee motivation and participation

**Support from the Top**

1. Enlist management support — management participation means management that is committed to getting energy savings with the same intensity that it would place on extracting similar profits from increasing production.
2. Have a senior company executive make an announcement concerning energy conservation early on in the program.
3. Management should check on the progress of the program and ask penetrating questions when results are not forthcoming.
4. Management should support the program by example — make sure there are no double standards!

**Building a dynamic team**

5. Recruit a capable co-ordinator and a plant energy conservation committee.
6. If possible, enlist a full-time person to direct the program.
7. Choose a co-ordinator who has enthusiasm, tact, technical ability and the ability to communicate with others.
8. Make sure representatives come from all parts of the company and be certain the plant engineering or plant facilities department is represented.
9. Encourage supervisors or department heads to participate in committee activities affecting their areas and assign them specific projects for investigation and follow-up.
10. Hold workshop sessions on how to involve plant people.
11. The committee should set annual objectives in energy savings for each part of the company, communicate these objectives to management and help organize the various departments.
12. Urge the committee to work hard to obtain union support.
13. Enlist the support of public relations and advertising people in the company — if there are such people.

14. In smaller companies with no public relations or advertising staffs, alternatives such as poster contests can be effective.

**Motivating through measurement**

15. Conduct an energy use survey, department by department, at the beginning of the program and at intervals thereafter.
16. Conduct some audits at night or on weekends since some inefficiencies can best be seen at these times.
17. Make an employee occasion out of a visit by the Energy Bus, if there is one in your province.
18. Start by aiming the program at one specific service — whichever offers the most significant potential improvement.
19. Make use of programs which will postpone the need for new facilities or services.
20. Set both long-range and short-term goals.
21. Set goals in familiar units that all workers will recognize.
22. Make regular reports on each department's performance.
23. Use the rivalry incentive — e.g. reports on the performance of other divisions or plants within the same company can create healthy competition.
24. Assign one employee to energy conservation maintenance and energy audit recording.
25. Install measuring devices to provide employees with a solid indication of their progress and give them an incentive to work harder.

**Involving all employees**

26. Come to grips with two frequently encountered employee attitudes: "Is there really an energy crisis?" and "What can my efforts do to reduce energy consumption?"

- Show them projections of an energy shortfall.
- Explain what energy conservation means for the company.
- Stress the dollar savings.

27. Stress the employee's crucial role in energy conservation.
28. Portray a new, evolving society based on conservation rather than consumption.
29. Show that energy conservation does not detract from status.
30. Show inconsistencies between excessive energy consumption and values held by employees.

**Publicizing energy conservation**

31. Make the energy conservation program highly visible by placing stickers on machines and posters on plant walls.
32. Put a rack of pamphlets in the lunch room or lobby.
33. Use tent cards on cafeteria tables, reception areas and on office desks.
34. Put signs and posters around the plant or office.
35. Make progress charts showing targets and achievements.
36. Put signs or stickers over taps and lights.
37. Use photographs on bulletin boards showing problem areas.
38. Write feature items for the company "house organ".
39. Circulate letters and memos from the company's top executive and the program co-ordinator.
40. Hold contests — logo contests, slogan contests or contests between departments or divisions of a plant.
41. Set up a suggestion box for energy conservation ideas.
42. Use incentives to encourage energy conservation.

**Employee education**

43. Distribute books on energy conservation to employees.
44. Send selected employees to seminars on energy conservation.
45. Set up energy conservation training programs for department heads or include energy conservation in existing training programs.

# SI USAGE

## Derived SI Units Having Special Names

| Quantity | Unit | Formula | Symbol |
|---|---|---|---|
| Frequency | hertz | $s^{-1}$ | Hz |
| Force | newton | $kg\text{-}m/s^2$ | N |
| Pressure or Stress | pascal | $N/m^2$ | Pa |
| Energy or Work | joule | N-m | J |
| Power | watt | J/s | W |
| Electric charge | coulomb | A-s | C |
| Electric potential | volt | W/A | V |
| Electric resistance | ohm | V/A | Ω |
| Electric conductance | siemens | A/V | S |
| Electric capacitance | farad | C/V | F |
| Magnetic flux | weber | V-s | Wb |
| Magnetic flux density | tesla | $Wb/m^2$ | T |
| Inductance | henry | Wb/A | H |
| Luminous flux | lumen | cd-sr | lm |
| Illuminance | lux | $lm/m^2$ | lx |

## Common Equivalents and Conversions

| Approximate Common Equivalents |
|---|
| 1 in. = 25 mm |
| 1 ft. = 0.30 m |
| 1 yard = 0.91 m |
| 1 mile = 1.6 km |
| 1 sq. in. = 6.5 $cm^2$ |
| 1 sq. ft. = 0.09 $m^2$ |
| 1 sq. yd. = 0.84 $m^2$ |
| 1 acre = 0.40 ha |
| 1 cu. in. = 16 $cm^3$ |
| 1 cu. ft. = 28 $dm^3$ |
| 1 cu. yd. = 0.76 $m^3$ |
| 1 quart (liq) = 1.1 ℓ |
| 1 gallon = 4.5 ℓ |
| 1 oz. (Avdp.) = 28 g |
| 1 lb. (Avdp.) = 0.45 kg |
| 1 hp (UK) = 0.746 kW |
| 1 lbf. = 4.4 N |
| 1 psi = 6.9 kPa |

## Some Other Derived SI Units

| Quantity | Unit | Symbol |
|---|---|---|
| Area | square metre | $m^2$ |
| Volume | cubic metre | $m^3$ |
| Velocity-angular | radian per second | rad/s |
| Velocity-linear | metre per second | m/s |
| Acceleration-angular | radian per second squared | $rad/s^2$ |
| Acceleration-linear | metre per second squared | $m/s^2$ |
| Density (mass per unit volume) | kilogram per cubic metre | $kg/m^3$ |
| Moment of force | newton metre | N-m |
| Viscosity-dynamic | pascal second | Pa-s |
| Thermal conductivity | watt per metre kelvin | W/(m-K) |
| Thermal flux density, Irradiance | watt per square metre | $W/m^2$ |
| Thermal capacity or Entropy | joule per kelvin | J/K |
| Permeability | henry per metre | H/m |
| Permittivity | farad per metre | F/m |
| Thermal resistance (R value) | square metre kelvin per watt | $m^2K/w$ |
| Energy density | joule per cubic metre | $J/m^3$ |

## SI PREFIXES

| Multiplying Factor | Prefix | Symbol |
|---|---|---|
| 1 000 000 000 000 000 000 = $10^{18}$ | exa | E |
| 1 000 000 000 000 000 = $10^{15}$ | peta | P |
| 1 000 000 000 000 = $10^{12}$ | tera | T |
| 1 000 000 000 = $10^{9}$ | giga | G |
| 1 000 000 = $10^{6}$ | mega | M |
| 1 000 = $10^{3}$ | kilo | k |
| 100 = $10^{2}$ | hecto | h |
| 10 = $10^{1}$ | deca | da |
| 0.1 = $10^{-1}$ | deci | d |
| 0.01 = $10^{-2}$ | centi | c |
| 0.001 = $10^{-3}$ | milli | m |
| 0.000 001 = $10^{-6}$ | micro | μ |
| 0.000 000 001 = $10^{-9}$ | nano | n |
| 0.000 000 000 001 = $10^{-12}$ | pico | p |
| 0.000 000 000 000 001 = $10^{-15}$ | femto | f |
| 0.000 000 000 000 000 001 = $10^{-18}$ | atto | a |

## Some Non-SI Units Used with the SI

| Unit | Symbol | Value in SI Units |
|---|---|---|
| minute | min | 1 min = 60 s |
| hour | h | 1 h = 3600 s |
| day | d | 1 d = 86 400 s |
| degree (of arc) | ° | $1^\circ = (\pi/180)$ rad |
| minute (of arc) | ′ | $1' = (\pi/10\,800)$ rad |
| second (of arc) | ″ | $1'' = (\pi/648\,000)$ rad |
| litre | l or ℓ | $1\ \ell = 1\ dm^3 = 10^{-3}\ m^3$ |
| tonne | t | $1\ t = 10^3$ kg = 1000 kg |
| hectare | ha | 1 ha = 10 000 $m^2$ |

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